Athens Journal of Sports - Volume 11, Issue 4, December 2024 – Pages 217-228

Leveraging Machine and Manual Feeding Method in Enhancing Badminton Smash Accuracy in Cagayan De Oro City

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This study examines the effectiveness of manual and machine shuttle feeding methods on badminton smash accuracy in novice tertiary education students over 12 weeks, using a quasi-experimental methodology. The study focused on male students enrolled in a Physical Education badminton course, evaluating their performance through pre-test and post-test assessments specifically on smash accuracy. The results showed substantial improvements in both intervention groups, with participants progressing from "less accurate" to "moderately accurate" smash performance. The manual technique exhibited a decrease in standard deviation from 1.78 to 1.56, indicating greater consistency in performance. Conversely, the machine technique resulted in a larger average increase in smash accuracy (from 3.55 to 5.47), though variability among participants increased (standard deviation rising from 2.11 to 2.43). Statistical analysis, using the Wilcoxon signed-rank test and the Mann-Whitney U test, confirmed significant improvements in smash accuracy within each group after the intervention, with no notable differences between the two methods in terms of performance gains. Both manual and machine feeding methods proved effective and comparable in enhancing badminton smash accuracy for novice players. The study underscores the importance of combining modern training tools with traditional coaching methods to meet individual learner needs and preferences. The findings provide valuable insights into badminton training, suggesting that utilizing both manual and machine feeding methods can improve outcomes by catering to different learning styles and enhancing skill development in badminton smash accuracy.

Keywords: *Badminton Smash Accuracy, Machine Shuttle-Feeding Method, Manual Shuttle-Feeding Method, Quasi-Experimental Study, Skill Enhancement in Badminton*

Introduction and Literature Review

Badminton, a racquet sport, is a mainstay in tertiary Physical Education (PE) programs due to its fast-paced, high-stakes gameplay, which demands expert technique, stamina, and control. However, research has largely focused on younger or general populations rather than tertiary-level students. This study addresses that gap (Dewi, 2021; Singh & Ambre, 2023), specifically examining how manual and machine shuttle feeding methods enhance smash accuracy among first-year college students.

The sport's minimal equipment requirements and indoor adaptability contribute to its widespread appeal. The dynamic postural adjustments required, such as jumps and rapid directional changes, make skilled play particularly challenging (Malwanage et al., 2022). To develop proficiency, especially in smash accuracy, players need

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https://doi.org/10.30958/ajspo.11-4-3 doi=10.30958/ajspo.11-4-3

professional training focused on biomechanics, including trunk rotation and limb coordination (Li, 2016; Zhang, 2017).

This study compares the effectiveness of manual and machine feeding methods on badminton smash accuracy under quasi-experimental conditions, addressing a notable gap in the literature. Most research has focused on overall badminton performance and fitness (Li, 2016; Phomsoupha & Laffaye, 2015), leaving a need for more studies on targeted training techniques to improve smash accuracy. The manual feeding method is a traditional approach where shuttlecocks are hand-thrown or fed with a racket, which is believed to enhance both general physical coordination and specific badminton smash skills (Alsaudi, 2020).

In contrast, technological advances have led to the development of automated shuttlecock-feeding machines, which offer a consistent, repetitive training environment. These machines are increasingly used in athletic training due to their ability to provide precise motion input while reducing the risk of injury (Smith et al., 2020; Xie et al., 2022).

This research is grounded in Vygotsky's Social Constructivism, Bruner's Theory of Scaffolding, and the Theory of Deliberate Practice. These frameworks suggest that skill development in badminton requires more than just time spent practicing—it requires social interaction and scaffolded learning to improve both mental and physical abilities (Ericsson et al., 2020; McLeod, 2019).

Conducted at a private university in Cagayan de Oro City, this quasi-experimental study aims to determine which training method is more effective in improving smash accuracy among novice players. Participants were assigned to either manual or machine-feeding interventions, with outcomes measured through pre- and post-tests using a standardized protocol. The findings are expected to offer valuable insights into current practices in tertiary badminton education and to inform training methods for higher levels of competition. In addition to improving smash technique and performance, the study aims to explore how best to integrate technology into sports training to achieve peak performance.

Methodology/Materials and Methods

This study employed a quasi-experimental methodology to evaluate the effectiveness of manual and machine shuttle feeding methods in improving smash accuracy among novice badminton players. Quasi-experimental designs are well-suited to educational contexts as they allow for controlled comparisons without random assignment (White, 2020; Gopalan et al., 2020).

Eighty male students from a beginner-level badminton PE class at a private university participated in the study. The students were pre-assigned to either the manual or machine feeding method, ensuring a balanced sample size between groups.

Two main tools were used in the study: the Health Appraisal Record, which assessed participants' fitness and ensured their safety, and the badminton smash test (Johnson & Nelson, 1969), which evaluated smash accuracy before and after the training period for both groups. Key equipment included a standard platform,

shuttlecocks, and a tightly strung badminton racket. To maintain consistency, the machine was used for shuttlecock feeding. Each participant had ten opportunities to score, with "Very Accurate" (ten hits) being the highest possible rating and "Inaccurate" (zero to two hits) being the lowest.

The study adhered to the highest ethical standards, as it was approved by the Research Ethics Committee of the host institution. Data collection spanned from August to November 2023 across 24 sessions. Ethical procedures included obtaining informed consent, ensuring strict compliance with data privacy regulations, and implementing safety measures.

The intervention was conducted in three phases over twelve weeks. In the Preliminary Phase (Weeks 1-4), participants focused on mastering form and technique while receiving immediate feedback. The Intermediate Phase (Weeks 5-8) reduced the amount of feedback to encourage independence. In the Final Phase (Weeks 9-12), participants applied their skills autonomously, culminating in a post-test to evaluate their progress. Sessions were held twice weekly for one hour each to maximize focus and minimize fatigue.

Results

Table 1 presents the result of the descriptive analysis of the badminton smash performance before and after the intervention.

Table 1. *Descriptive Analysis of Badminton Smash Performance before and after the Interventions*

Range	Description	Manual Method				Machine Method			
		Pretest		Post-test		Pretest		Post test	
		f	%	f	%	f	%	f	%
10 hits	Very accurate	0	0	1	1.67	1	1.67	2	3.33
8-9 hits	Accurate	1	1.67	2	3.33	0	0	13	21.67
5-7 hits	Moderately accurate	15	25	37	61.67	21	35	21	35
3-4 hits	Less accurate	24	40	18	30	16	26.67	17	28.33
0-2 hits	Inaccurate	20	33.33	2	3.33	22	36.67	7	11.67
Total		60	100	60	100	60	100	60	100
Mean		3.57		5.10		3.55		5.47	
Description		Less accurate		Moderately accurate		Less accurate		Moderately accurate	
SD		1.78		1.56		2.11		2.43	

The table shows that at the start of the study, both groups exhibited a "less accurate" mean score of slightly over 3.5, which reflects the skill level of beginners. However, in the post-test, the mean scores in both groups increased to over 5.0. There was a notable increase in the frequency of "moderately accurate" hits in the manual method group, rising from 25% to over 61%.

Additionally, the manual technique group's standard deviation decreased from 1.78 to 1.56, suggesting that this intervention, likely due to the individualized feedback and one-on-one interaction during training, promoted more consistent

accuracy among participants. In contrast, the machine technique group's standard deviation increased from 2.11 to 2.43, indicating a wider range of results. This suggests that participant interactions with mechanical training aids may vary, potentially leading to higher peaks in performance (as indicated by the mean increase) but also greater variability in outcomes.

Moreover, the study shows that the manual method resulted in a higher frequency of hits classified as "moderately accurate" in the post-test, indicating that it helps participants focus on refining and correcting their technique. This implies that personalized coaching can lead to more consistent performance across the group. While the machine method also led to an increase in accuracy, the greater variability suggests that improvements varied more among participants. This could indicate that some players adapt more quickly to automated feeding, while others may require more time to adjust.

Table 2 presents the results of the Wilcoxon signed-rank test comparing badminton smash performance before and after the intervention.

Table 2. *Result of the Wilcoxon Signed-rank Test comparing the Badminton smash Performance be-fore and after the Intervention*

	Statistics	Manual Method	Machine Method
Badminton smash accuracy	Pre-test mean	3.57	3.55
	Post-test mean	5.10	5.47
	W	26	14.0
	p	<0.001*	<0.001*
	Effect size (RBC)	-1.00	-1.00

* Significant at 0.001 level

The table shows the results of the Wilcoxon signed-rank test for badminton smash accuracy before and after the intervention using both manual and machine methods. The Wilcoxon signed-rank test ($W = 26$, $p < 0.001$) indicates significant improvement, rejecting the null hypothesis and suggesting a meaningful difference between the pre-test and post-test scores in the manual method group. Supporting this, the Rank Biserial Correlation (RBC = -1.00) demonstrates that the post-test scores entirely surpass the pre-test scores, meaning every value in the post-test is greater than every value in the pre-test.

The study emphasizes the practical effectiveness of targeted badminton training interventions, with post-intervention scores consistently exceeding pre-intervention scores for all participants. This underscores the robustness of the training methods and the ability of structured training, whether manual or machine-based, to significantly improve the skill levels of novice players. The findings suggest that these methods could be applied to other technical aspects of badminton or even other sports, potentially leading to widespread improvements in athletic performance. The success of these interventions could promote the development of personalized and adaptive training programs.

Table 3 presents the results of the Mann-Whitney U test, which compares the effectiveness of each intervention in enhancing badminton smash accuracy. The test produced a statistic of 2050.50 with a p-value of 0.178. As a result, the null hypothesis (Ho2), which states that there is no significant difference between the two groups

regarding the increase in badminton smash accuracy, cannot be rejected. Additionally, the RBC (0.139) indicates a minimal effect size. While one group achieved a slightly higher average score than the other, the difference between the manual and machine feeding methods in terms of improving badminton smash accuracy is minimal.

Table 3. *Result of the Mann-Whitney U Test to Compare the Increments of the Manual and Machine Groups in enhancing badminton Smash Accuracy*

Badminton smash accuracy	Manual Method	Machine Method	W	p	RBC
Mean	1.53	1.92	2050.50	0.178	0.139
SD	1.17	1.56			

Based on the findings, both interventions are comparably effective in helping novice players improve their badminton smash accuracy. This gives coaches more flexibility in choosing training methods that suit their players' needs, preferences, and available resources. When designing badminton training programs, it is important to consider the fundamental principles of effective training.

Discussion

Problem 1: How did the participants perform in the Badminton smash accuracy test before and after the interventions?

The study shows that in terms of badminton smash performance, the manual method led to a higher frequency of "moderately accurate" hits in the post-test, suggesting that this method helps participants refine their technique. This implies that personalized coaching fosters more consistent technique across the group. The machine method also resulted in improved accuracy, but the variation in results suggests that some participants adapted to automated feeding faster than others.

Before the pre-test, the researcher personally asked participants in the manual group about their badminton experience. Some participants mentioned playing during leisure time, while others had competed in intramural games. Participating in organized sports or leisure activities can help develop skills outside formal settings (Fuchs & Osikominu, 2016). The researcher recognized that the participants had a mix of beginner and intermediate skill levels, based on these informal conversations during the first week of the intervention.

During the intervention, the researcher noticed that many participants struggled to hit the shuttlecock when it was thrown manually, indicating poor hand-eye coordination. This suggests that participants had low neurodevelopmental readiness for sports participation at the start of the experiment (Patel et al., 2021). They needed to learn the correct form and biomechanics for a successful badminton smash, as the shuttle's release angle and clearance height are directly affected by the player's body position. Timing, technique, and fundamental skills are essential for executing an effective smash.

In the post-test, noticeable skill improvements were observed. Targeted training programs, such as drill exercises and hand-eye coordination practices, can enhance badminton smash skills (Alsaudi, 2020). Participants developed better timing and hand-eye coordination, supported by research showing that smash skills improve through training approaches that emphasize timing and synchronization (Akbari, 2017). Studies also confirm the connection between smash power, accuracy, and body alignment, showing that participants' coordination and strength improved after the intervention (Li et al., 2023; Indora et al., 2022).

The group eventually learned the proper stroke form and biomechanics required for the smash, including racquet placement, angle at impact, and body tension (Li et al., 2023). Biomechanical analysis explains the improvements in participants' smash abilities after the intervention (Brahms, 2014). Additionally, trunk rotation, or the "X-factor," enhances power in the forehand smash by creating intense muscular contractions and increasing racquet speed (Zhang et al., 2016).

In the machine method group, participants also acknowledged limited experience in smashing before the pre-test. The machine that fed shuttlecocks was new to them, but it motivated them to learn. Research suggests that unfamiliar training tools can inspire new learners to engage in practice (Aslam et al., 2019). However, some participants still had difficulty hitting the shuttle during the experiment, further emphasizing the complexity of badminton skill development (Gogoi & Duwarah, 2017).

During the post-test, improvements in smashing accuracy were observed, with participants advancing from "less accurate" to "moderately accurate." They also became more independent, performing the skill without the instructor's guidance.

Problem 2: How do the participants in each group compare their badminton smash performance before and after the intervention?

> Ho1. The participants in each group do not significantly differ in their Badminton smash accuracy before and after the interventions.

In the comparison of badminton smash performance between the groups before and after the intervention, the researcher observed that manual shuttle feeding allowed for real-time adjustments, enabling the shuttle feeder to wait until participants were properly positioned before releasing the shuttle. This created an immediate feedback loop, allowing players to correct elements like grip, footwork, arm swing, and follow-through. The personalized attention given through manual feeding is believed to significantly enhance the accuracy of badminton smashes. Unlike automated methods, manual feeding emphasizes human interaction and judgment, reinforcing the researcher's confidence in its effectiveness.

From a Social Constructivist perspective, Vygotsky's theory suggests that learners benefit from guidance provided by more skilled individuals, which is mirrored in manual badminton instruction. In this setting, the coach plays the role of the 'more informed other,' providing real-time feedback and personal coaching that falls within the learners' Zone of Proximal Development (ZPD) (Vygotsky & Cole, 1978). By maintaining tasks that are challenging yet achievable, the manual approach fosters

skill development through social interaction, adapting instruction to the individual's needs.

During training, coaches using the manual method corrected players' technique, offering a customized approach that aligns with Vygotsky's belief in the importance of direct interpersonal communication for skill acquisition (Schunk, 2012). In line with this, research (Wee et al., 2019) highlights that manual feeding has proven benefits for enhancing athletic performance, although the study did not separate manual from machine approaches. The focus on body alignment and trunk rotation during an overhead smash (Zhang, 2019) further supports the idea that manual methods provide immediate corrections that help enhance performance. However, despite these findings, there remains a lack of extensive research focusing specifically on the manual feeding approach.

In contrast, the machine approach offers consistency in practice by ensuring uniformity in shuttle speed and landing position. This stability allows players to focus on developing timing and coordination without the variability inherent in manual feeding. Over time, this repetition leads to improvements in students' motor coordination and skill consistency, demonstrating the method's effectiveness in improving smash accuracy.

Bruner's Scaffolding Theory reinforces the benefits of the machine-based approach. Scaffolding offers temporary support until learners achieve competency, allowing them to practice consistently without external variability. The machine delivers shuttles at a consistent trajectory, enabling players to master key elements of the smash. As players' skills improve, external assistance is gradually reduced, mirroring how scaffolding is removed when no longer needed. This highlights the machine's role as a scaffold, facilitating skill development through structured repetition.

The effectiveness of the machine-based approach is further demonstrated by the significant increase in post-test scores (Wilcoxon signed-rank test, Table 2), as supported by previous research (Yousif & Yeh, 2011; Xie et al., 2019; Aslam et al., 2019; Punithan et al., 2023). Technologies such as CAD, 3D printing, and AI in modern badminton training tools, like the Shuttlecock Propulsion Machine and IBTR (Intelligent Badminton Training Robot), enhance players' ability to develop consistency and precision in smashes.

The success of both interventions in improving smash accuracy depended largely on the duration (12 weeks, 24 sessions). This extended training period allowed participants to learn, practice, and refine their skills. Regular, repetitive practice strengthened key muscles and reduced performance anxiety, allowing players to focus on improving both technique and power. As a result, both groups demonstrated significant performance improvements post-intervention.

Manual feeding, with its personalized guidance, offered participants tailored feedback, improving their precision and skill through real-time corrections. On the other hand, the machine-fed group benefitted from regular, intensive practice that likely improved their timing and strength. Comparing pre- and post-intervention results revealed the effectiveness of both methods in enhancing badminton smash technique. These findings provide valuable insights into balancing human-guided

practice with machine-assisted training to achieve the best outcomes in badminton training.

Problem 3: Do the two groups of participants differ significantly in their Badminton smash performance increments?

> Ho2. The two groups of participants do not significantly differ in their Badminton smash accuracy increments.

When comparing the improvements in badminton smash accuracy between the manual and machine groups, the Deliberate Practice Theory (Ericsson & Harwell, 2019) provides a relevant framework. This theory emphasizes that performance enhancements are largely driven by focused, repetitive practice combined with feedback. Both manual and machine training methods in this study offered participants ample opportunities for repetition and feedback, which likely explains why both methods were equally successful in improving smash accuracy. This perspective suggests that deliberate practice, when aimed at refining specific skills and providing immediate feedback, is effective in both manual and machine-based training approaches.

Another theoretical interpretation of the data can be drawn from Vygotsky's Zone of Proximal Development (ZPD) (Vygotsky & Cole, 1978), which proposes that optimal learning occurs when learners are supported but not entirely autonomous. Both training techniques (manual and machine) likely positioned participants in their ZPD by providing an appropriate level of challenge and support necessary for skill improvement. This framework supports the idea that both methods created a learning environment that was conducive to skill enhancement by balancing difficulty and assistance (McLeod, 2019).

The study's findings align with previous research that underscores the significance of structured, repetitive training in developing technical skills in sports. Both human and machine feeding techniques are effective in this regard (Zhang et al., 2016). Technological advancements in sports training have been found to be as effective as traditional methods, further supporting the notion that machine feeding is a viable alternative to manual feeding (Xie et al., 2019).

Moreover, research by Punithan et al. (2023) highlights the critical role that the quality of practice and feedback loops play in sports training. The study's design, which incorporated feedback from both manual and machine approaches, was likely instrumental in ensuring their effectiveness. This finding is supported by research from Alsaudi (2020), which emphasizes the importance of personalized training regimens that cater to individual skill levels and needs. This could explain the comparable improvements observed in both groups in the study.

The real-world implications of these findings for badminton training and coaching are significant. Since both human and machine feeding methods resulted in similar improvements in smash accuracy, coaches have the flexibility to choose between these approaches based on factors such as budget, personal preference, or training environment without compromising the quality of their players' skill development. These results reinforce the idea that the most critical elements in

improving badminton skills are high-quality practice sessions and the integration of feedback, rather than the specific type of training equipment used. This suggests that modern training tools can complement traditional coaching methods, providing players with diverse options for skill improvement in badminton.

Conclusions

The study successfully met its objective of evaluating the effectiveness of manual and machine shuttle feeding methods in improving badminton smash accuracy among beginners. Both intervention groups exhibited significant improvements in smash accuracy, with a slight edge in effectiveness observed in the machine feeding approach. The findings underscore that both methods are highly effective in developing smash accuracy, particularly for novice players.

The study also confirmed the relevance of several key theories—Deliberate Practice Theory, Bruner's Theory of Scaffolding, and Vygotsky's Social Constructivism —in enhancing badminton smash accuracy. Regular, systematic practice, following scaffolding principles, allowed players to progressively develop their smash skills over the 12-week intervention. Training exercises were designed to provide gradual, adaptive support, which was reduced as the players became more proficient. Additionally, the social interaction and guided feedback central to Social Constructivism facilitated the acquisition of skills, demonstrating how both manual and machine feeding created structured learning environments that supported players' Zone of Proximal Development (ZPD) and skill improvement.

The study offers valuable insights for sports educators, coaches, and practitioners looking to design effective badminton training programs. It recommends integrating technology-assisted training, highlighting the benefits of machine feeding in improving smash accuracy for beginners. However, it also emphasizes the importance of manual feeding for providing personalized feedback and real-time adjustments, suggesting that combining both approaches could yield even better results. The choice of which intervention to use depends on factors such as resource availability, individual preferences, and the specific nature of the training environment.

For tertiary physical education (PE) students, the study advises discussing their preferences and training goals with their instructors to develop a personalized approach. Physical educators are encouraged to create training protocols that incorporate both manual and machine feeding methods to optimize the development of smash accuracy. Badminton coaches may tailor training sessions to focus on key aspects of the smash technique—such as timing, footwork, and racket positioning—while ensuring access to quality equipment for both manual and machine feeding. Finally, the study suggests that future researchers explore the comparative effectiveness of various training approaches across different skill levels, sports, and populations, with an emphasis on long-term skill retention and the transferability of skills to game situations.

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